No appreciable change in kangaroo carcase weights during cold storage: implications for compliance with minimum harvest carcase weight restrictions

Adam J. Munn[1,*], and Nicole Payne[2]

[1]School of Biological Sciences, University of Sydney, NSW 2006, Australia
Fax +61 2 9351 4119; Phone +61 2 9351 2932; email adam.munn@bio.usyd.edu.au

[2]NSW Department of Environment and Climate Change, PO Box 2111, Dubbo NSW 2830, Australia
Fax +61 2 6884 8675; Phone +61 2 6883 5343; email nicole.payne@environment.nsw.gov.au

*To whom correspondence should be directed

ABSTRACT

Abstract The commercial harvest of kangaroos in Australia is regulated by various state government agencies. They control the number of kangaroos that can be harvested annually with the view to ensuring that the harvest remains ecologically and economically sustainable. In addition to controlling the harvest quotas, some agencies impose minimum weight restrictions on harvested animals, which may assist with maintaining viable breeding populations. However, harvesting usually occurs in remote regions and carcases may be stored refrigerated for up to 10-14 d before being inspected for compliance with minimum weight restrictions. Consequently, there is concern that weight loss during cold storage, particularly in small carcases close to the minimum limit, could lead to harvesters being wrongly prosecuted or fined for breaching the minimum carcase weight licence condition. We found that for two species of kangaroo, the large eastern grey kangaroo (*Macropus giganteus*; liveweight 30-70 kg) and the smaller red-necked wallaby (*M. rufogriseus*; liveweight 10-24 kg), carcase weight loss after 10 days cold storage was negligible. There was no significant effect of species on carcase weight change after 10 days cold storage and their pooled weight change averaged just -75.0 $\pm$ 18.0 g, or 0.35 $\pm$ 0.08% of initial carcase weight. This level of weight loss was significantly different from a hypothesised weight change of zero (Z = -4.17, P < 0.001). However, after an additional four days of cold storage, average weight change in the smallest carcases (the red-necked wallabies) was not significantly different from zero (Z = -1.65, P > 0.05).

Key words: Carcase dehydration, kangaroo, marsupials, harvesting.

Introduction

Kangaroo harvesting in Australia is an established and burgeoning industry that contributes around AUS$230 million per anum to Australia's agricultural sector (Kelly 2005). Traditionally, agriculturalists and pastoralists have viewed kangaroos mainly as 'pests', but there is increasing interest in their viability as a commodity in their own right, and particularly as a model for conservation through sustainable use (Grigg 1989, 2002; Ampt and Baumber 2006). This is particularly so as national and international markets for kangaroo products continue to expand, while sheep and wool prices are declining (Ampt and Baumber 2006). Harvested kangaroos are processed mainly for human consumption or for pet meat, in addition to processing for skins/leather and related products. Additionally, kangaroos may offer indirect economic returns through non-traditional sources like eco-tourism (Croft 2000; Higginbottom *et al.* 2004). Consequently, recent focus for kangaroo management has shifted away from pest management and toward sustainable harvesting (Anon. 2007), thereby helping to ensure the viability of kangaroos as a useful resource. Moreover, ecologically sustainable harvesting of kangaroos has implications for their contribution to total grazing pressures, particularly in arid and semi-arid sheep rangelands (Olsen and Low 2006; Dawson and Munn 2007).

Five species of large kangaroo are harvested commercially on Australia's mainland; the red kangaroo *Macropus rufus*, the eastern *M. giganteus* and western *M. fuliginosus* grey kangaroos, the common wallaroo/euro *M. robustus*, and the whip-tailed wallaby *M. parryi* (see Olsen and Braysher 2000). In Tasmania, two species of wallaby are also commercially harvested; Bennetts or Red-neckedwallaby *Macropus rufogriseus* and Pademelon *Thylogale billardierii* (see Olsen and Braysher 2000). The commercial harvesting of kangaroos is managed at the State level by way of kangaroo management plans (KMPs) or equivalent; governed by the Department of Environment and Climate Change (DECC) in New South Wales, the Department of Environment and Heritage in South Australia, the Department of Environment and Conservation in Western Australia and the Queensland Parks and Wildlife Service as part of the Environmental Protection Agency in Queensland. Each State's management plan regulates harvesting through the issuing of hunting tags for commercial culling and also for pest mitigation.

Currently, most kangaroo populations are harvested at around 8-10% of total population per year, which is well below the 10-20% allowed by most KMPs (Olsen and Low 2006; Anon. 2007). This level of harvesting is also well below the maximum levels predicted for sustainable

management (McLeod *et al*. 2004). However, in addition to controlling the total number of animals harvested, there is concern about the age and size structure of the harvested populations (Wilson, 1975; Pople 2003; McLeod *et al*. 2004). Therefore, some state plans impose strict minimum weight restrictions for harvested animals. The setting of minimum weights aims to avoid harvesting young animals, particularly females, so that they may have opportunity to breed prior to culling, putatively maintaining population recruitment, but also removes small, less profitable skins from the market (Pople 2003; Kelly 2005).

The set minimum carcase weight varies between states and according to processing procedures for either human or pet food consumption. In NSW, where this study was carried out, the minimum weight for carcases dressed in the manner typical of processing for human consumption is 13 kg, and 12 kg for carcases dressed in the manner typical of processing for pet meat processing; human consumption carcases must retain the heart, liver and lungs for meat quality testing prescribed by the Australian Standard for Hygienic Production of Game Meat for Human Consumption (ARMCANZ 1997). It is assumed that these organs sum to an average of 1 kg, justifying the higher minimum weight requirements for human consumption carcases. In NSW, the DECC regularly inspects harvested carcases to check compliance with these minimum weight restrictions. However, kangaroos are usually collected in remote and regional areas and may be stored in field refrigerators, or chillers, for up to 10 days before being transported to a meat processor. Consequently, carcases may be inspected some time after their initial slaughter and there is concern that they may lose weight during cold storage, presumably through dehydration. Consequently, there is a risk that professional kangaroo shooters could be wrongly prosecuted or fined for breaching the minimum carcase weight license condition. Carcase weight change may also have implications for meat quality (Wynn *et al.* 2004). We therefore investigated the potential for carcase weight loss in two species of kangaroo, the large eastern grey kangaroo (*M. giganteus*; liveweight 30-70 kg), which is one of the harvested species in NSW, and the smaller red-necked wallaby (*M. rufogriseus*; liveweight 10-24 kg) which is not subject to harvesting. By using the smaller species, the red-necked wallabies, we were able fully explore the potential for carcase weight change in animals that were below the minimum weight allowed for commercially harvested kangaroos, thereby providing data that encompassed the entire weight spectrum relevant for enforcing compliance with this licence condition.

Methods

Chiller storage conditions

The kangaroo carcases used in this experiment were stored in a typical field chiller (cold storage unit; width 2.4 m; height 2.6 m, length 6.0 m). Chiller ambient temperature (T_a; ± 0.5 °C) and relative humidity (%RH; ± 0.6%) were measured hourly using a digital temperature/humidity logger (Hygrochron iButton, model DS1923; Maxim Integrated Products, CA USA). T_a and %RH were recorded along the centre of the chiller at the front, mid and rear of the facility.

Animals and carcase weight change

The eastern grey kangaroos (n = 26 males; n = 14 females) used in this study were collected by a licensed professional kangaroo shooter as part of a commercial harvesting operation in southeastern New South Wales. The animals were collected over one night in accordance with DECC NSW KMP (Anon. 2007) and relevant licences issued under the *National Parks and Wildlife Act 1974*. Carcases were dressed at the point of harvest and all carcases were transported to our field chiller and refrigerated by 0300 h (i.e. before the prescribed 2 h after dawn; ARMCANZ 1997). Carcases were dressed for pet meat processing (i.e. total organ evisceration, decapitation and forepaws and feet removed; Fig 1). On entry to the chiller, each dressed carcase was weighed to ± 0.05 kg (Salter Scales, Lansvale, NSW) to provide an initial 'hot' weight. Carcases were hung suspended from the right leg and in a manner that allowed air to flow over the entire animal surface and within the thoracic cavity (Fig. 1), with the view of maximising potential for water loss by dehydration.

Figure 1. Kangaroo carcases prepared for pet meat consumption and hung adequately spaced to maximise airflow across the furred surface and within the exposed thoracic cavity. Photo: A. Munn.

The red-necked wallabies (n = 3 males; n = 5 females) used in this study were collected as part of a separate study conducted by Munn *et al.* (unpublished). Red-necked wallabies are not commercially harvested in NSW, but their average body mass is at the low end of the typical weight range for the four large species of commercially harvested kangaroo. Because all macropodids (kangaroos and wallabies; family Macropodidae) have the same basic body shape and form, we used the red-necked wallabies to investigate carcase weight changes in kangaroos that would normally be well below the legal minium weights allowed

for the larger, commercially harvested species (mainly the red, eastern and western grey kangaroos and the euro/wallaroo). The red-necked wallabies were slaughtered by a lethal intracardiac injection of sodium pentobarbitone (160mg kg^{-1}) between 0730 h and 0900 h on Day 1 of the experiment. Each carcase was exsanguinated and eviscerated via a ventral incision before being carefully packed into plastic bags and stored cold for transportation. The carcases were then transported to our field chiller within 4.5 h of slaughter. On arrival, the carcases were dressed for pet-meat processing as per the eastern grey kangaroos (above). Carcases were weighed to ± 0.05 kg (Salter Scales, Lansvale, NSW) and hung suspended by the right leg in a manner that allowed air to flow over the entire animal surface and within the thoracic cavity.

On Day 1 of the experiment, all carcases were weighed (± 0.05 kg) between 1400 and 1500 h. Carcases were then weighed at approximately the same time on Days 2, 4, 5, 7 and 10. After 10 days the eastern grey kangaroos were removed for processing. The red-necked wallaby carcases were stored for an additional four days before a final weight was measured on Day 14.

Statistical analysis

We compared weight changes (absolute change in grams) between initial carcase weights and those on Day 10 of cold storage in the red-necked wallaby and eastern grey kangaroos using a General Linear Model (GLM). Assumptions for GLM were tested using Kolmogorov-Smirnov test for normality and Levene's test for homogeneity of variances. Initial ('hot') carcase weight was square root transformed to achieve normal distribution and homogeneity of variances with respect to species. However, because of the broad range in body weights for the male eastern grey kangaroos (13.7 – 49.9 kg; n = 26) and their overrepresentation in the data compared females (13.4 – 21.1 kg; n = 14), we could not achieve homogeneity of variances in initial carcase weight for sex. Sex was therefore excluded as a factor from our study, but is unlikely to be important biologically as male and female kangaroos share the same body shape and form (Fig. 1), with body weight being the primary difference between sexes. Therefore, we investigated carcase weight loss after Day 10 of cold storage using a GLM with species as a random factor and the square root of initial carcase mass as a covariate.

We measured carcase weights of the red-necked wallabies after 14 days cold storage (i.e. Day 14 – initial weight; g) to determine whether smaller carcases experienced increased weight loss after additional cold storage. Gross carcase weight change (g) for the red-necked wallabies by Day 10 and Day 14 were compared using a paired, two-tailed t-test. Absolute carcase weight change (g) for the red-necked wallabies on both Day 10 and Day 14 was also compared to theoretical weight change of zero (g) using a one-sample Z-test (Zar 1999).

All stats were performed using Minitab for Windows. Data are presented as means ± standard error of the mean (SEM). Differences were considered statistically different at $p \leq 0.05$.

Results

Chiller storage conditions

The chiller maintained relatively constant T_as throughout the entire experiment, at an average of -0.44 ± 0.08 °C (Fig. 2). Spikes in T_a were associated with carcase weighing sessions on Day 1, 2, 4, 5, 7, 10 and 14, but these periods each lasted less than 1 h, and T_a was quickly restored (Fig. 1).

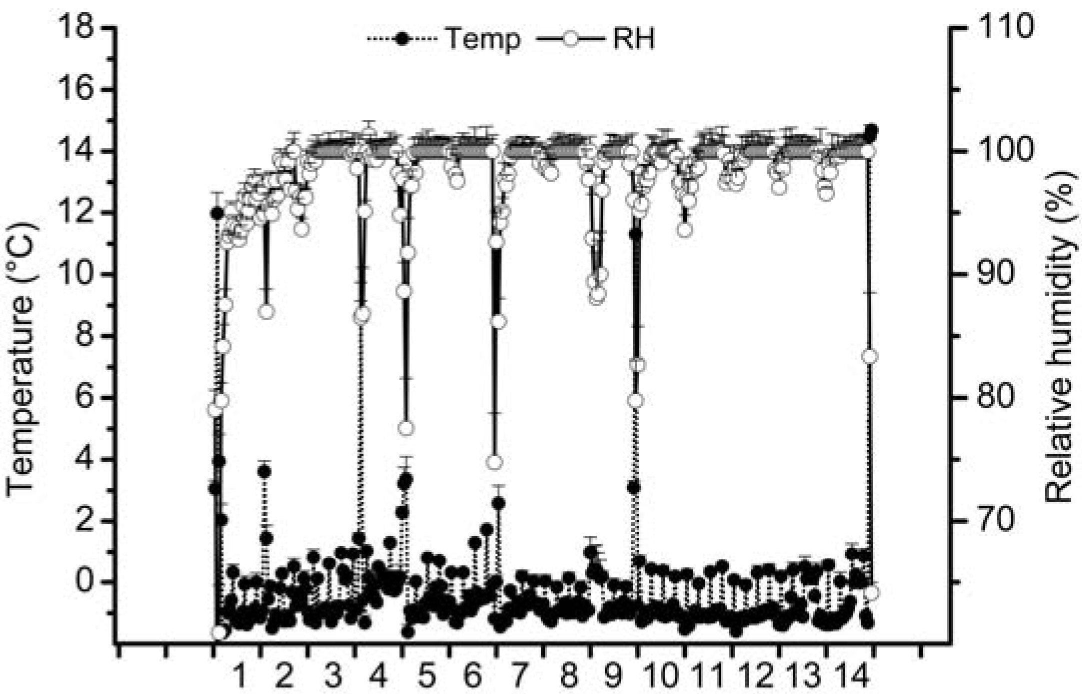

Figure 2. Average hourly chiller conditions for ambient temperature (Temp; °C) and relative humidity (RH; %) from Day 1 to Day 14 of cold storage.

Average chiller %RH throughout the experiment was 98.0 ± 0.3%. However, chiller %RH was comparatively low on Day 1 of carcase storage, increasing from ca. 50% at 1500 h (i.e. 12 h after the eastern grey carcases entered storage, but immediately following Day 1 weighing) and increasing to around 97% by 0900 h on Day 2 and 100% by 0500 h on Day 3. Troughs in %RH were evident during carcase weighing sessions on Day 1, 2, 4, 5, 7, 10 and 14 (Fig. 2).

Carcase weight changes

Carcase weights for the red-necked wallabies (Fig. 3) and eastern grey kangaroos (Fig. 4) were relatively constant throughout the entire experiment (see Table 1). There was no significant difference in the absolute weight change (g) of the red-necked wallaby carcases between their initial weight and that measured on Day 10 and Day 14 of cold storage, the values being -37.5 ± 26.3 g (Initial *versus* Day 10) and -75.0 ± 45.3 g (Initial *versus* Day 14), respectively (paired-$t_{(2)}$ = 1.43, DF = 7; $P > 0.05$; Table 1). Moreover, the levels of carcase weight change (g) for the red-necked wallabies by Day 10 and Day 14 of storage were each not significantly different from zero (Day 10, $Z = -1.43$, $P > 0.05$; Day 14, $Z = -1.65$, $P > 0.05$). Conversely, the eastern greys level of weight change after 10 days cold storage was significantly different from zero at an average of -82.5 ± 20.8 g ($Z = -3.96$, $P < 0.0001$), but this change was less than 1.0 % of their initial carcase mass (Table 1).

There was no significant effect of species on the level of carcase weight change after 10 days of cold storage (Table 2). Initial carcase weight was not a significant covariate for absolute carcase weight change after 10 days ($P > 0.05$; Table 2). Overall, when the kangaroo carcases were pooled for species, their average weight change after 10 days was just –75.0 ± 18.0 g, or 0.35 ± 0.08% of initial carcase weight (Table 1). Although small, this level of weight change was significantly different from a hypothesised weight change of zero ($Z = -4.17$, $P < 0.001$).

Discussion

Weight loss from properly prepared kangaroo carcases (i.e. eviscerated, cleaned and exsanguinated) could result from residual body water/fluids evaporating via the carcase's exposed surfaces; through the furred skin as post-mortem trans-epidermal evaporation and from the thoracic and abdominal walls exposed by evisceration. Therefore, it may be expected that smaller kangaroo carcases, particularly those close to the minimum legal weights prescribed for commercial harvesting, could lose more weight during cold storage relative to larger carcases because of their higher surface area to volume ratios. However, we found that the smaller carcases were not more or less likely to lose weight than the larger carcases. Indeed, the average weight change observed for the smallest of the kangaroo carcases (i.e. the red-necked wallabies) was not significantly different from zero after 10 or 14 days cold storage.

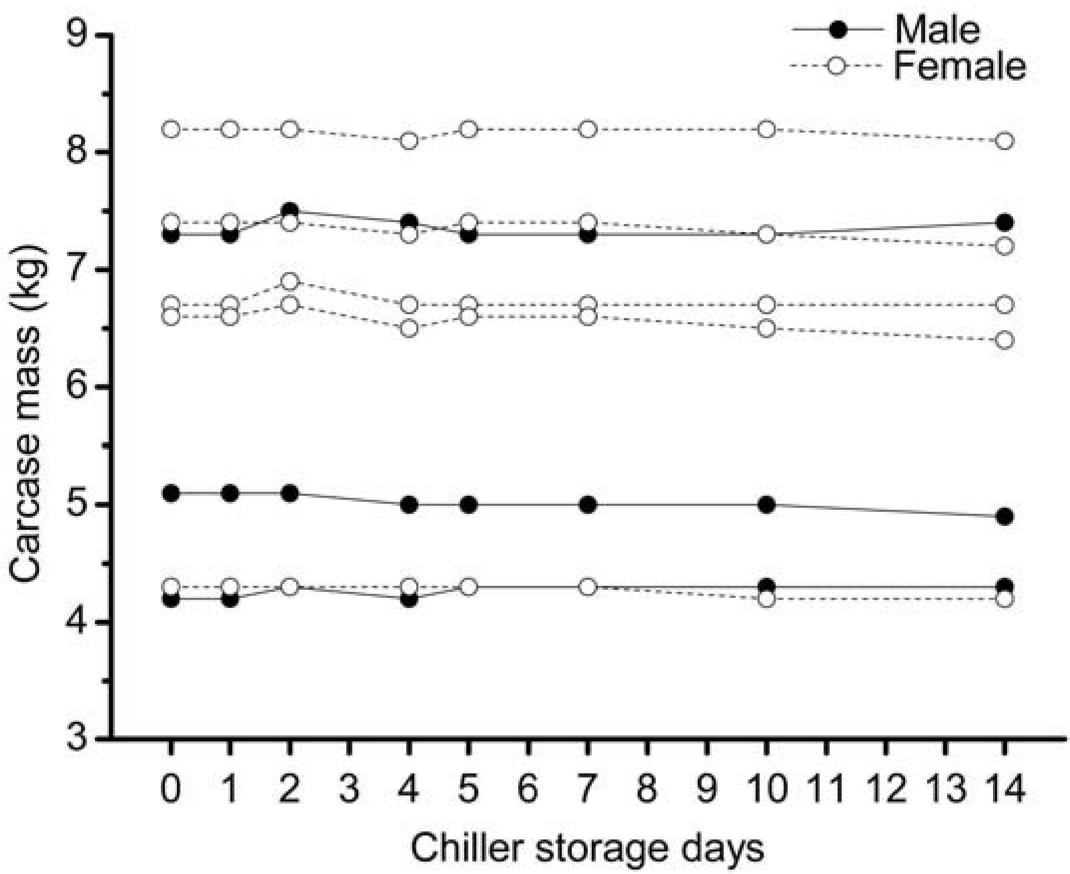

Figure 3. Initial (Day zero) and daily weights (kg) for the red-necked wallaby carcases measured on Day 1 – Day 14 of cold storage.

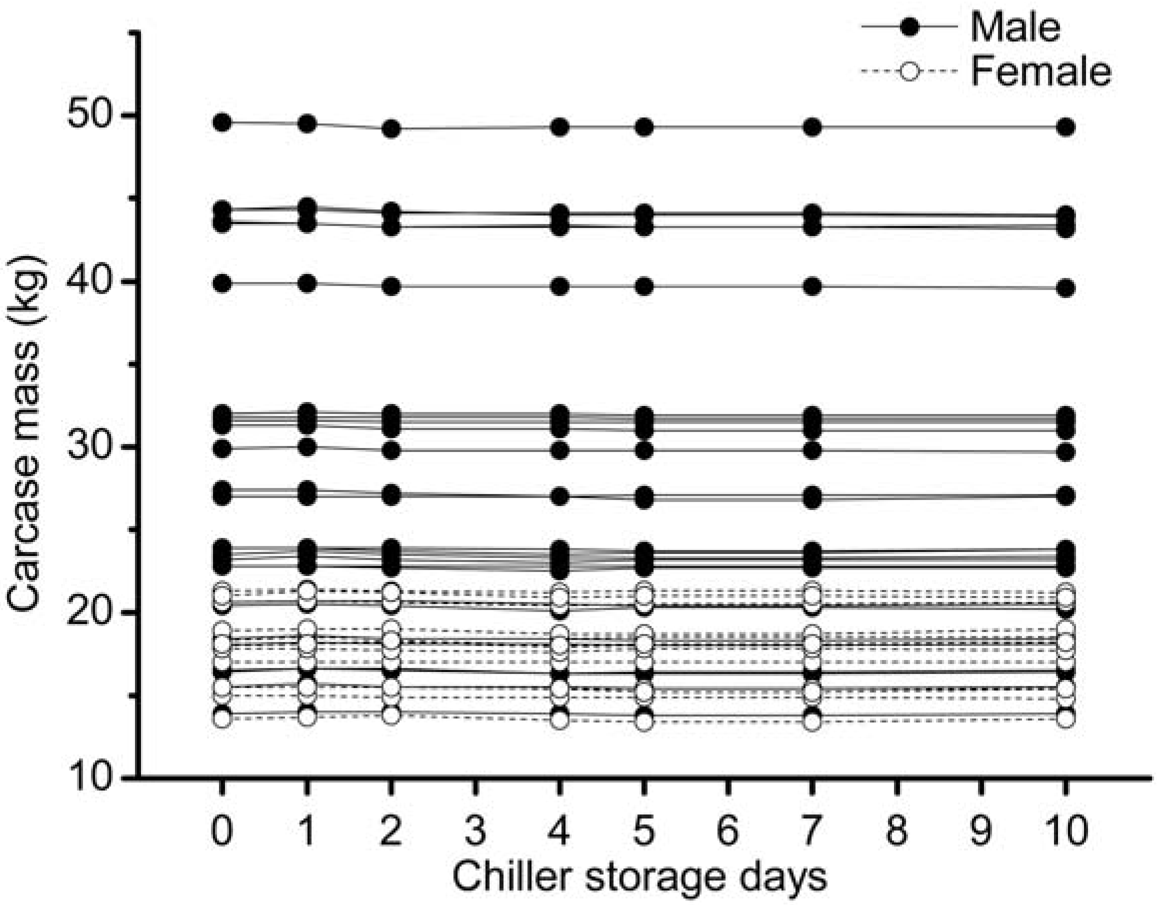

Figure 4. Initial (Day zero) and daily weights (kg) for the eastern grey kangaroo carcases measured on Day 1 – Day 10 of cold storage.

Table 1. Mean (± SEM) change in kangaroo carcase weights after 10 and/or 14 days chiller storage (see text for statistical differences within species; values in parenthesis are as a proportion of initial carcase weight).

Species	Initial carcase weight (kg)	Change after 10 days (g)	Change after 14 days (g)
Red-necked (n = 8)	6.2 ± 0.5	-37.5 ± 26.3 (-0.60 ± 0.4%)	-75.0 ± 45.3 (-1.2 ± 0.7%)
Eastern grey (n = 40)	24.7 ± 1.5	-82.5 ± 20.8 (-0.33 ± 0.5%)	-
Combined (n = 48)	21.6 ± 1.6	-75.0 ± 18.0(-0.35 ± 0.08%)	-

Table 2. General Linear Model for carcase weight changes for red-necked wallabies (n =8) and eastern grey kangaroos (n = 40) combined, with species as random factor and initial carcase weight (square root transformed) as a covariate.

Source	*F*-ratio	*P*-value
Square root initial carcase weight	2.01	0.163
Species	2.82	0.331

Generally, the macropodid marsupials (kangaroos, wallabies and rat kangaroos) have the same basic body shape and form (Fig. 1). Therefore, that we found no significant effect of kangaroo species on carcase weight changes after 10 days cold storage (Table 1) indicates that our results should be representative for most harvested species spanning a live-weight range of 5-50 kg, but particularly for the larger red and western grey kangaroos and for the euro/wallaroo. Overall, we found that for carcases prepared for pet meat consumption, the average weight changes after 10 days cold storage was negligible (< 1% initial carcase mass). However, it is worth noting that although we did detect a slight, but significant, change of average carcase weight of -75 g after 10 days, this level of weight loss was actually within the precision limits of our measurements (i.e. to the nearest 100 g). It is therefore very unlikely that significant weight loss could lead to borderline-weight carcases being recorded as underweight as a consequence of dehydration during cold storage of at least 10 days. However, these results are applicable mainly to kangaroo carcases prepared for pet meat processing, and there are different considerations for carcases prepared for human consumption.

The minimum weight required for carcases that are prepared for human consumption accounts for the retention of vital organs required for food standards testing (ARMCANZ 1997). These organs include the heart, liver and lungs which are generally high in water content, but it is difficult to predict how these organs might change during cold storage. However, for chiller conditions comparable to

those reported here (i.e. low and constant T_as and high %RHs) there is no reason to suspect that carcases prepared for human consumption would behave differently to the carcases used here; there simply was no gradient for evaporation and so water loss from organs would also have been negligible. Nonetheless, it should be noted an eastern grey kangaroo carcase at a minimum allowable weight of 13 kg for human consumption is assumed to contain organs contributing 1 kg to their carcase weight, or 7.7%. Thus, even if organ dehydration was 100% (which is very unlikely, if not impossible, at these temperatures and storage times), the absolute maximum level of possible carcase weight loss must be less than 7.7% of initial carcase weight, because the organs dry matter would still be retained. Therefore, although further investigation is needed to fully appreciate how carcases prepared for human consumption may change during chiller storage, we recommend that a maximum error of 7% below minimum weight could be allowable for carcases prepared for human consumption. However, we found that for carcases prepared for pet meat there was negligible weight change after 10 days cold storage, and any carcases found to be below the minimum weight restriction could not be defended on the basis of potential water (weight) losses as a consequence of cold storage, provided the chiller conditions are as required for meat processing by the food safety standards (ARMCANZ 1997).

Acknowledgements

This project was supported by a grant to AJM by the New South Wales Department of Environment and Climate Change Kangaroo Management Program. The eastern grey kangaroos were harvested in accordance with the *National Parks and Wildlife Act 1974*. The red-necked wallabies were sourced from a separate project conducted by AJM and carried out under New South Wales National Parks and Wildlife licence S11905 and with the approval from the University of New South Wales Animal Care and Ethics Committee (ACEC04/13). Sincere thanks to the professional shooters who participated in this project and to Greg Bates and Vacik Distributors for providing access to harvested carcases and for use of a field chiller. Sincere thanks to Tania Rose and Peter Munn for their assistance with weighing carcases and to Dr Steve McLeod for comments and improvements on earlier versions of this manuscript.

References

Ampt P. and Baumber A. 2006. Building connections between kangaroos, commerce and conservation in the rangelands. *Australian Zoologist* 33(3): 398-409.

Anon. 2007. NSW Commercial Kangaroo Harvest Management Plan 2007-2011. The NSW Department of Environment and Climate Change, Sydney. (available at www.environment.nsw.gov.au; follow links to 'Kangaroo Management')

ARMCANZ 1997. Australian Standard for Hygienic Production of Game Meat for Human Consumption. Victoria, Australia, CSIRO Publishing.

Croft D. 2000. Sustainable use of wildlife in western New South Wales: Possibilities and problems. *Rangeland Journal* 22:88-104.

Dawson T.J. and Munn A.J. 2007. How much do kangaroos of differing age and size eat relative to domestic stock?: implications for the arid rangelands. Pp 96-101 in *Animals of Arid Australia: out on their own?* edited by C. Dickman, D. Lunney and S. Burgin S., Royal Zoological Society of New South Wales, Mosman NSW, Australia.

Grigg G.C. 1989. Kangaroo harvesting and the conservation of arid and semi-arid rangelands. *Conservation Biology* 3: 194-197.

Grigg G.C. 2002. Conservation benefit from harvesting kangaroos: status report at the start of a new millennium. Pp. 53-76 in *A Zoological Revolution: using native fauna to assist its own survival.* edited by D. Lunney and C. R. Dickman, Royal Zoological Society of New South Wales, Mosman NSW and the Australian Museum, Sydney.

Higginbottom K., Northrope C.L., Croft D.B., Hill B. and Freedline E. 2004. The role of kangaroos in Australian tourism. *Australian Mammalogy.* 26(1): 23-32

Kelly J. 2005. Kangaroo Industry Strategic Plan 2005-2010. Rural Industries Research and Development Corporation, Barton ACT.

McLeod S. R., Hacker R. B. and Druhan J. P. 2004. Managing the commercial harvest of kangaroos in the Murray-Darling Basin. *Australian Mammalogy* 26(1): 9-2.

Olsen P. and Braysher M. 2000. *Situation analysis report: Current state of scientific knowledge on kangaroos in the environment, including ecological and economic impact and effect of culling.* Prepared for the Kangaroo Management Advisory Committee, The NSW Department of Environment and Conservation National Parks and Wildlife Service (available at www.environment.nsw.gov.au; follow links to 'Kangaroo Management')

Olsen P. and Low T. 2006. Situation analysis report update on current state of scientific knowledge on kangaroos in the environment, including ecological and economic impact and effect of culling. Prepared for the Kangaroo Management Advisory Committee, The NSW Department of Environment and Conservation national parks and Wildlife Service (available at www.environment.nsw.gov.au; follow links to 'Kangaroo Management')

Pople T. 2003. Setting minimum carcase weights. *The Journal of the Australian Kangaroo Industry*, Number 34.

Wilson G. R. 1975. Age structures of populations of kangaroos (Macropdidae) taken by professional shooters in New South Wales. *Australian Wildlife Research* 2: 1-9.

Wynn P., Beaton A. and Spiegel N. 2004. *Meat quality of kangaroos*. Publication No. 04/151, Rural Industries Research and Development Corporation, Barton ACT

Zar J.H. 1999. Biostatistical Analysis, 4th edition. Prentice-Hall Inc., Sydney.